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Caused by Kozyavkin© method changes in hand function parameters in children with spastic form of cerebral palsy and their EEGs, HRVs and GDVs accompaniments

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Abstract

Background. Earlier we reported that in children with spastic forms of cerebral palsy (SFCP) after two-week course of rehabilitation by Kozyavkin© method the hand function tests changed ambiguously and such a variety of changes is due to differently directed changes in the background activity of the nerve centers. **Aime:** to identify the peculiarities of changes in the parameters of EEG, HRV and GDV in children with favorable and unfavorable changes in the parameters of the functions of the hands. **Material and research methods.** The object of observations were 14 children (6 girls and 8 boys) aged 8÷15 years with SFCP. State motor development at GMFCS was on II÷IV level. Functional status of the hand with MACS was at II÷III level. The estimation of hand function carried out by Dynamometry (D), Box and Block Test (BB) and Nine Hole Peg Test (NHP). We registered also components of muscular tone by device "NeuroFlexor" (Aggero MedTech AB, Sweden), HRV and EEG parameters simultaneosly by hardware-software complex "Cardiolab+VSR" and "NeuroCom Standard" respectively (KhAI Medica, Kharkiv, Ukraine) as well as GDV parameters by “GDV Chamber” (“Biotechprogress”, St-Pb, RF). **Results.** The method of cluster analysis retrospectively highlighted two distinct groups-clusters. In 9 children, rehabilitation led to favorable changes in the parameters of the function of the hands, while in 3 children they turned out to be unfavorable. The method of discriminant analysis revealed that unfavorable changes are accompanied by a decrease in the asymmetry of the θ- and δ-rhythms, the spectral power density (SPD) of β-rhythm in loci F8 and Fp1, instead, it increases in loci O1 and T3, leading to left-sided lateralization of the β-rhythm. At the same time, the SPD of the α-rhythm in locus O1 and the θ-rhythm in locus F4 rises as well as its Deviation. These changes in the EEG are accompanied by a reduction in vagalis and an increase in sympathetic tones. Among the GDVs parameters, an increase in the area of the GD Image in the frontal projection, coupled with a decrease in its Entropy in the frontal and left projections, was found. Instead, favorable changes in the parameters of the hand function are accompanied by opposite changes in the listed EEGs, HRVs and GDVs parameters or their absence. **Conclusion.** Among 14 observed children with spastic forms of cerebral palsy caused by Kozyavkin© method changes in functional tests of hand are favorable in 11. Adverse changes in 3 children are accompanied by characteristic changes in a number of EEGs, HRVs and GDVs parameters, which in the long run will be corrected by electrostimulation of the corresponding nervous structures.

Keywords: Cerebral palsy, Dynamometry, Box and Block Test, Nine Hole Peg Test, Neural, Elastic and Viscous components of Muscular Tone, EEG, HRV, GDV, Intensive Neurophysiological Rehabilitation System by Kozyavkin© method.

Резюме

Передумови. Раніше ми повідомляли, що у дітей із спастичною формою церебрального паралічу (СФЦП) після двотижневого курсу реабілітації методом Козявкіна© тести на моторну функцію рук змінювалися неоднозначно, і такі зміни обумовлені різноспрямованими змінами фонової активності нервових центрів. **Мета**: виявлення особливостей змін параметрів ЕЕГ, варіабельності ритму серця (ВРС) та газорорядної візуалізації (ГРВ) у дітей зі сприятливими та несприятливими змінами параметрів функцій рук. **Матеріал і методи.** Об'єктом спостережень було 14 дітей (6 дівчат та 8 хлопчиків) у віці 8-15 років з СФЦП. Стан моторного розвитку за шкалою GMFCS був на рівні II÷IV. Функціональний стан рук за шкалою MACS був на рівні II÷III. Оцінка функції рук здійснювалася за допомогою динамометрії (D), тесту “коробка і блоки” (BB) та тесту “дев'ять лунок і кілків” (NHP). Ми реєстрували також компоненти м'язового тонусу за допомогою пристрою "NeuroFlexor" (Aggero MedTech AB, Швеція), параметри ВРС та ЕЕГ одночасно за допомогою апаратно-програмного комплексів "Cardiolab + VSR" та "NeuroCom Standard" (ХАІ Медика, Харків, Україна), а також параметри ГРВ "GDV Chamber" ("Biotechprogress", СПб, РФ). Повторне тестування проводили після двотижневого курсу реабілітації. **Результати.** Методом кластерного аналізу ретроспективно виділено дві чітко відмінні між собою групи-кластери. У 9 дітей реабілітація спричиняла сприятливі зміни параметрів функції рук, натомість у 3 дітей вони виявились несприятливими. Методом дискримінантного аналізу виявлено, що несприятливі зміни параметрів функції рук супроводжуються зменшенням асиметрії тета- і дельта-ритмів, щільності спектральної потужності (SPD) бета-ритму в локусах F8 і Fp1, натомість вона підвищується в локусах O1 і T3, що веде до лівосторонньої латералізації бета-ритму. Разом з тим, підвищується SPD альфа-ритму в O1 і тета-ритму в F4, а також відхилення частоти останнього. Такі зміни ЕЕГ супроводжуються зниженням вагусного і підвищенням симпатичного тонусів. З-поміж параметрів ГРВ виявлено збільшення площі зображення у фронтальній проекції в поєднанні із зменшенням його ентропії у фронтальній і лівій проекціях. Натомість сприятливі зміни параметрів функції рук супроводжуються протилежними змінами перелічених параметрів або їх відсутністю. **Висновок.** Несприятливі зміни у 3 дітей супроводжуються характерними

змінами низки параметрів ЕЕГ, ВРС і ГРВ, які в перспективі будуть піддані корекції шляхом електростимуляції відповідних нервових структур.

Ключові слова: церебральний параліч, динамометрія, тести “коробка і блоки” та “дев'ять лунок і кілків”, нервовий, еластичний і в’язкий компоненти м’язевого тонусу, ЕЕГ, ВРС, ГРВ, система інтенсивної нейрофізіологічної реабілітації Козявкіна©.

INTRODUCTION

Earlier we reported that after two-week course of Intensive Neurophysiological Rehabilitation System (INRS) officially recognized as Kozyavkin© method [1-3] the parameters of the hands function tests in 108 children with spastic forms of cerebral palsy (SFCP) are significantly improved. In total the effectiveness of the restoration of functional parameters of hands by Kozyavkin© method makes average 23,3±1,6% versus 3,5±1,4% in control. However, the average values obscure significant differences between individual children. In particular, in 58% of patients, changes are very tangible, in 22% moderate, while in 20% are minor [4]. In another contingent of 29 children, we found that reducing neural component of muscle tone (NCMT) stated in 79,3% cases from 7,6±1,0 N to 1,6±0,5 N (direct difference: -6,0±0,8 N), while in 13,8% cases changes were not detected and in 2 children only NCMT increased from 1,6 to 3,4 and from 4,6 to 6,1 N respectively [5,6].

It is known about abnormalities in autonomous nervous system (ANS) in patients with CP [7-9]. Obviously, these abnormalities are associated with CNS damage. We have recently discovered relationships between the parameters heart rate variability (HRV) as markers of ANS activity and background EEG activity [10,11]. Proceeding from this we hypothesized that such a variety of changes in NCMT is due to ambiguous changes in the background activity of the nerve centers. For their evaluation are available HRV and Electroencephalography (EEG) methods (about of Neuroimaging in the conditions of Ukraine can only dream). Since such children are not always able to register EEG and HRV due to uncontrolled movements, the search for other methods for evaluating neural activity remains relevant.

In 1996 KG Korotkov created a new scientific approach, based on the digital videotechnics, modern electronics and computer processing quantitative data, called as method gas discharge visualization (GDV bioelectrography). Parallel uses the terms Kirlianography and Electrophotonics. Method of GDV, essence of which consists in registration of photoelectronic emission of skin, induced by high-frequency electromagnetic impulses, allows to estimate integrated psycho-somatic state of organism. It is considered that parameters of GDV, taken off without filter, characterizes the **current** psychophysiological condition of organism while registered with a filter characterizes vegetative regulation at the level of **stable** physiological processes [12,13]. Since ambiguous attitude to the method (between excellent and fickle), previously we conducted the study on its verification and have shown that GDV parameters are correlated with HRV [14] and EEG [15] parameters. In another study, we have shown that GDV parameters can change with variation in other functional parameters of the body [16].

We have recently been shown that changes in manual functional tests and NCMT are determined by variety in parameters of EEG and HRV as well as GDV [17,18].

In this study, we set the goal to identify the peculiarities of changes in the parameters of EEG, HRV and GDV in children with favorable and unfavorable changes in the parameters of the hand functions.

MATERIAL AND RESEARCH METHODS

The object of observations were 14 children (6 girls and 8 boys) aged 8÷15 years with Spastic Forms of Cerebral Palsy. Diagnose, Stage, Phase as well as

Gross Motor Function Classification System [19] and Manual Ability Classification System [20] levels are given in the Table 1.

Table 1. Clinical characteristics of the observed children

Child	Gender	Age	Diagnose	Stage	Phase	GMFCS	MACS
Hou L	Girl	14	**G80.0 CCP: spastic tetraplegia**	movement by turning	lying to the control head	4	3
Myk	Boy	10	**G80.1 CCP: spastic diplegia**	crawling on their bellies	independent seat	4	3
Pet	Girl	10	**G80.1 CCP: spastic diplegia**	walking on the knees	getting up at the support	4	3
Hou D	Girl	14	**G80.1 CCP: spastic diplegia**	walk with aids	independent seat	3	3
Hav	Boy	10	**G80.1 CCP: spastic diplegia**	walk with aids	rising support near	3	3
Pav	Boy	9	**G80.1 CCP: spastic diplegia**	walk with aids	rising support near	3	2
Boj A	Boy	15	**G80.1 CCP: spastic diplegia**	walk with aids	self-rising	2	2
Boj D	Boy	15	**G80.1 CCP: spastic diplegia**	independent moves	self-rising	2	2
Vor	Boy	9	**G80.1 CCP: spastic diplegia**	independent moves	self-rising	2	2
Kry	Boy	8	**G80.2 CCP: spastic hemiplegia Left**	independent moves	self-rising	2	2
Lan	Girl	12	**G80.2 CCP: spastic hemiplegia Left**	independent moves	rising support near	2	2
Kul	Girl	12	**G80.1 CCP: spastic diplegia**	altenative crawling	independent seat	4	3
Kuch	Girl	13	**G80.1 CCP: spastic diplegia**	walk with aids	rising support near	3	3
Str	Boy	12	**G80.2 CCP: spastic hemiplegia Left**	independent moves	self-rising	1	1

The estimation of hand function carried out by Dynamometry (D), Box and Block (BB) test and Nine Hole Peg (NHP) test. To measure the strength of the hand we used dynamometer of “Jamar” company [21]. The essence of the BB test by V Mathiowetz et al [22] is to determine the number of wooden cubes that patient can shift from one box to the second in a minute. The essence of NHP test [23,24] is to determine how long the patient can turn each hand insert and then remove wooden 9 pegs in 9 holes in the wooden bar.

For each test we calculated Laterality Index (LI) using the equation:

$$LI=100\%\cdot(Right - Left)/0,5\cdot(Right + Left)$$

We registered also Neural, Elastic and Viscous components of Muscle Tone by device “NeuroFlexor” (Aggero MedTech AB, Sweden). Recent studies have indicated that device is suitable for measurement changes in spasticity during CP treatment [6,25-28].

The next morning in a sitting position we recorded during 7 min electrocardiogram in II lead by hardware-software complex "CardioLab+HRV" ("KhAI-Medica", Kharkiv, Ukraine) to assess the parameters of HRV as markers of vagal and sympathetic outflows. For further analysis the following parameters HRV were selected. Temporal parameters (Time Domain Methods): heart rate (HR), the standart deviation of all NN intervals (SDNN), the square root of the mean of the sum of the squares of differences between adjacent NN intervals (RMSSD), the percent of interval differences of successive NN intervals greater then 50 ms (pNN_{50}). Spectral parameters (Frequency Domain Methods): spectral power (SP) bands of HRV: high-frequency (HF, range 0,4÷0,15 Hz), low-frequency (LF, range 0,15÷0,04 Hz), very low-frequency (VLF, range 0,04÷0,015 Hz) and ultra low-frequency (ULF, range 0,015÷0,003 Hz). We calculated also relative SP all bands as well as classical indexes LF/HF and LFnu [29-31].

Simultaneosly with HRV we recorded EEG for 25 sec using hardware-software complex “NeuroCom Standard” (KhAI Medica, Kharkiv, Ukraine) monopolar in 16 loci (Fp1, Fp2, F3, F4, F7, F8, C3, C4, T3, T4, P3, P4, T5, T6, O1, O2) by 10-20 international system, with the reference electrodes A and Ref on the ears tassels. Among the parameters considered the average EEG amplitude (μV), average frequency (Hz), frequency deviation (Hz), index (%), coefficient of asymmetry (%) as well as absolute (μV^2/Hz) and relative (%) spectral power density (SPD) in the standard frequency bands: β (35÷13 Hz), α (13÷8 Hz), θ (8÷4 Hz) and δ (4÷0,5 Hz) in all loci, according to the instructions for the device. In addition, we calculated Laterality Index (LI) for SPD each Rhythm using formula:

$$LI, \% = \Sigma\ [200 \bullet (Right - Left)/(Right + Left)]/8$$

The Kirlianogram have been registered by the method of GDV with the use the device “GDV Chamber” (“Biotechprogress”, SPb, RF) [12].

After testing children within two weekes received a classic course rehabilitation (a detailed description is provided in the manual [3]), then repeated the tests listed.

Digital material is treated by methods cluster [32,33] and discriminant [34] analyses with the use of package of softwares "Statistica-5.5" and algorithm of Truskavets’ scientific school of balneology [16].

RESULTS AND DISCUSSION

The first phase was carried out Cluster analysis of changes in hand function. Use of Cluster analysis makes possible the simultaneous consideration of all the signs. Considering the totality of characteristics of persons undertaken in their relationship and conditionality of some of these (derivatives) other (main determinants) allows as to make a natural classification that reflects the nature of things, their essence. It is believed that knowledge of the essence of the object is to identify those of its quality properties that actually define the object, distinguish it from other [33].

Clustering cohort of persons is realized by iterative k-means method. In this method, the object belongs to the class Euclidean distance to which is minimal. The main principle of the structural approach to the allocation of uniform groups consists in the fact that objects of same class are close but different classes are distant. In other words, a cluster (the image) is an accumulation of points in n-dimensional geometric space in which average distance between points is less than the average distance from the data points to the rest points [32].

Clusters appeared clearly delineated, as evidenced by the ratio between Distances from Respective Cluster Center (Table 1) and Euclidean Distances between Clusters (40,5).

Table 1. Cluster Analysis Summary.
Members of Cluster N1 and Distances from Respective Cluster Center. Cluster contains 3 cases

	Kuc	Kul	Str
Distance	10,3	6,91	16,8

Members of Cluster N2 and Distances from Respective Cluster Center. Cluster contains 11 cases

	Hav	Pav	Vor	Lan	HL	Kry	Pet	Myk	HD	BA	BD
Distance	17,8	44,8	9,23	2,32	4,30	5,49	9,64	6,37	7,21	9,27	8,62

It is stated (Table 2) that members of the major cluster due to the course of rehabilitation increases the speed of manipulation of objects with both hands, as well as their strength (D). This is combined with a decrease in the neural component of the muscle tone (NCMT) of the left hand in the absence of changes in the viscous and elastic components.

Table 2. Cluster Analysis Summary. Changes in Hand Function and Analysis of Variance

Changes in Variables	Cluster No. 1 (3)	Cluster No. 2 (11)	Betwe-en SS	Within SS	η^2	R	F	signif. p
BB Left, blocks/min	-4,9±0,2	+2,9±0,6	140,6	38,6	0,784	0,886	43,7	$<10^{-4}$
NHP Right, sec	+63±23	-23±7	16214	8839	0,647	0,804	22,0	$<10^{-3}$
NHP Left, sec	+66±7	-21±13	18027	18753	0,490	0,700	11,5	,005
BB Right, blocks/min	-5,0±1,0	+4,1±1,6	195,9	277,1	0,414	0,644	8,5	,013
D Left, kG	-0,4±2,5	+3,0±0,8	27,76	111,65	0,199	0,446	3,0	,110
Viscous CMT, Newtons	-0,36±0,06	+0,12±0,14	0,546	2,24	0,196	0,443	2,9	,113
Neural CMT, Newtons	+1,7±5,8	-5,2±2,0	115,4	663,5	0,148	0,385	2,1	,174
Elastic CMT, Newtons	+1,4±0,4	+1,2±0,9	,115	90,25	0,001	0,040	0,02	,904
D Right, kG	+3,1±3,8	+3,5±1,8	0,39	432,2	0,001	0,030	0,01	,918

Notes.
$\eta^2=Sb^2/(Sb^2+Sw^2)$; $R=\eta$; $F=[Sb^2(n-k)]/[Sw^2(k-1)]$, where
Sb^2 is Between Variance;
Sw^2 is Within Variance;
n is number of persons (14);
k is number of groups-clusters (2).

Thus, in 11 children, functional changes are clearly favorable. Instead, in three children, the D and NCMT indices have changed uncertainly, and speed tests, unfortunately, have deteriorated, that is, it should be noted that adverse changes in the hands functions. Interestingly, this was accompanied by a negligible but statistically significant decrease in viscous and elastic components of the muscle tone.

In the second stage carried out Analysis of Variance and ranking variables for coefficient η^2. It was found that the largest contribution to the distribution of clusters gives the BB test of the left hand and the NHP test of the right hand, while the contributions of the elastic CMT and the right-hand dynamometry are worthless.

In the third stage carried out Discriminant analysis (method forward stepwise [34]). This analysis is applied in order to identify exactly those indicators of the functions of hands, in which the clusters essentially differ from each other. Contrary to the expectation inspired by the results of the dispersion analysis, the program included a discriminant model of the change of D of the right hand, whereas the analogue index of the left hand was out of the model (Table 3). This indicates that the discriminant (distinctive) sign is not the average value, but the variance of this variable, as well as its Laterality.

Table 3. Discriminant Function Analysis Summary. Changes in Hand Function
Step 6, N of vars in model: 6; Grouping: 2 grps
Wilks' Lambda: 0,0131; approx. $F_{(7,6)}$=65; $p<10^{-5}$

Variables currently in the model	Unfavorable changes (3)	Favorable changes (11)	Wilks' Λ	Partial Λ	F-remove	p-level	Tolerancy
BB Left, blocks/min	-4,9±0,2	+2,9±0,6	,094	,139	37,1	,001	,094
NHP Right, sec	+63±23	-23±7	,013	,979	,1	,733	,019
NHP Left, sec	+66±7	-21±13	,020	,664	3,0	,132	,008
BB Right, blocks/min	-5,0±1,0	+4,1±1,6	,036	,366	10,4	,018	,036
D Right, kG	+3,1±3,8	+3,5±1,8	,089	,148	34,6	,001	,022
D Laterality, %	+19±15	0±5	,027	,492	6,2	,047	,064
NHP Laterality, %	+1±27	0±15	,015	,854	1,0	,350	,013
Variables currently not in the model			Wilks' Λ	Partial Λ	F to enter	p-level	Tolerancy
D Left, kG	-0,4±2,5	+3,0±0,8	,012	,885	,652	,456	,004
Neural CMT, N	+1,7±5,8	-5,2±2,0	,013	,967	,170	,697	,485
Viscous CMT, N	-0,36±0,06	+0,12±0,14	,012	,941	,312	,600	,792
Elastic CMT, N	+1,39±0,40	+1,17±0,90	,013	1,000	,002	,968	,586
BB Laterality, %	-0,4±3,2	+4,5±6,7	,013	1,000	,001	,971	,026

Next, the 6-dimensional space of discriminant variables transforms into one-dimensional space of a canonical discriminant function (canonical root), which is a linear combination of discriminant variables. The discriminating (differentiating) ability of the root characterizes the canonical correlation coefficient (r*) as a measure of connection, the degree of dependence between groups and a discriminant function.

Table 4 presents raw (actual) and standardized (normalized) coefficients for discriminant variables. The raw coefficient gives information on the absolute contribution of this variable to the value of the discriminative function, whereas standardized coefficients represent the relative contribution of a variable independent of the unit of measurement. They make it possible to identify those variables that make the largest contribution to the discriminatory function value.

Table 4. Summary of Stepwise Analysis and Coefficients for Canonical Variables (Changes in Hand Function)

	Parameters of Wilk's Statistics					**Coefficients for Canonical Variables**		
Variables currently in the model	F to enter	p-level	Λ	F-va-lue	p-level	Standar-dized	Struc-tural	Raw
BB Left, blocks/min	43,7	10^{-4}	,215	44	10^{-4}	-3,046	-,220	-1,698
BB Right, blocks/min	2,4	,163	,027	43	10^{-4}	4,255	-,097	,886
D Right, kG	14,4	,003	,093	53	10^{-5}	6,241	-,003	1,040
NHP Right, sec	4,7	,056	,064	49	10^{-5}	1,041	,156	,038
NHP Left, sec	2,1	,178	,051	41	10^{-5}	6,544	,113	,166
D Laterality, %	6,2	,047	,013	65	10^{-4}	-2,837	,050	-,150
NHP Laterality, %	3,5	,099	,036	43	10^{-4}	3,330	,001	,068
	r*=0,993; Wilks' Λ=0,013; $\chi^2_{(7)}$=37;p<10^{-5}						**Constant**	-2,102

The same is the full structural coefficients, that is, the coefficients of correlation between the discriminant root and variables. The structural coefficient shows how closely variable and discriminant functions are related, that is, what is the fate of information about the discriminant function (root) contained in this variable.

As you can see, the root inversely reflects the information on changes in BB tests and D of Right hand. Instead, with a another constellation of functional parameters is discrimint root tied in a reverse manner.

The sum of products of raw coefficients on the value of discriminant variables together with the constant gives the value of discriminant function (root) for each child and allow their visualization (Fig. 1).

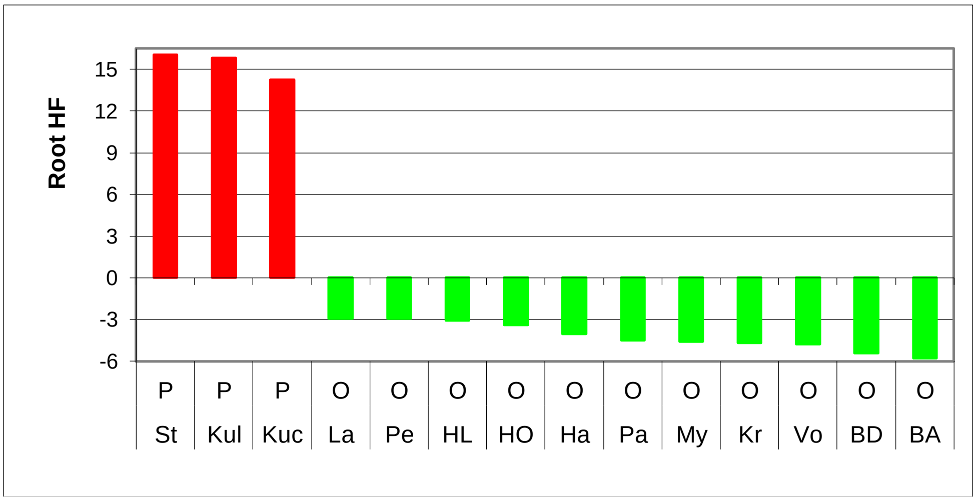

Fig. 1. Individual values of canonical Root of unfavorable (P) and favorable (O) changes in Hand Function

Even at first glance it is possible to state a drastically difference between the changes in Hand Function in members of two clusters. Positive individual columns show decrease of these variables, which correlate with the canonical discriminant root inversely, and increase of directly correlated variables. The visual impression is documented by calculating the square of Mahalanobis distance between the values of discriminant roots: $D^2_M=447$ ($F=53$; $p<10^{-4}$).

The same discriminan parameters can be used to identify (classify) the belonging of one or another child to an unfavorable or favorable group. This purpose of discriminant analysis is realized with the help of classifying (discriminant) functions (Table 5).

Table 5. Coefficients and Constants for Classification Functions of Changes in Hand Function

Variables currently in the model	Unfavorable changes (3)	Favorable changes (11)
	p=,214	p=,786
BB Left, blocks/min	-29,231	4,002
NHP Right, sec	,557	-,194
NHP Left, sec	3,099	-,141
BB Right, blocks/min	15,820	-1,515
D Right, kG	18,667	-1,689
D Laterality, %	-2,728	,215
NHP Laterality, %	1,306	-,031
Constants	-155,6	-3,724

These functions are special linear combinations that maximize differences between groups and minimize dispersion within groups. The coefficients of the classifying functions are not standardized, therefore they are not interpreted. An object belongs to a group with the maximum value of a function calculated by summing the products of the values of the variables by the coefficients of the classifying functions plus the constant. In this case, we can retrospectively recognize members of two groups unmistakably.

Now let's consider the changes of exactly what EEGs and HRVs parameters reflect opposite changes in the parameters of the hands functions.

Among EEGs parameters revealed (Table 6) that unfavorable changes are accompanied by a decrease in the asymmetry of the θ- and δ-rhythms, the SPD of β-rhythm in loci F8 and Fp1, instead, it increases in loci O1 and T3, leading to left-sided lateralization of the β-rhythm. At the same time, the SPD of the α-rhythm in locus O1 and the θ-rhythm in locus F4 rises as well as its Deviation (variability). These changes in the EEG are accompanied by a reduction in vagalis and an increase in sympathetic tones. Instead, favorable changes in the parameters of the hand function are accompanied by opposite changes in the listed EEGs, HRVs and GDVs parameters or their absence.

Table 6. Discriminant Function Analysis Summary. Changes in EEGs and HRVs parameters
Step 10, N of vars in model: 10; Grouping: 2 grps
Wilks' Lambda: 0,0327; approx. $F_{(10,3)}$=8,89; p=0,049

Variables currently In the model	Unfavorable changes (3)	Favorable changes (11)	Wilks' Λ	Parti-al Λ	F-re-move	p-level	Tole-rancy
Θ-rhythm Asymmetry, %	-27±12	+8±4	,033	,988	,0	,859	,511
Δ-rhythm Asymmetry, %	-33±13	+9±7	,123	,265	8,3	,063	,151
Β-rhythm Laterality, %	-54±3	-8±10	,037	,872	,4	,555	,173
F8-β SPD, µV²/Hz	-32±22	+41±27	,076	,430	4,0	,140	,239
HF HRV, %	-3,4±2,8	+6,6±4,3	,053	,622	1,8	,270	,077
Θ-rhythm Deviation, Hz	+1,00±0,29	-0,05±0,30	,040	,818	,7	,474	,184
LFnu HRV, %	+5,2±3,9	-11,2±4,9	,061	,534	2,6	,204	,093
O1-β SPD, µV²/Hz	+178±81	-5±58	,050	,657	1,6	,300	,181
O1-α SPD, µV²/Hz	+116±20	-20±50	,071	,462	3,5	,158	,080
F4-θ SPD, %	+4,3±1,7	-2,1±2,9	,093	,350	5,6	,099	,147
Variables currently not In the model			Wilks' Λ	Parti-al Λ	F to enter	p-level	Tole-rancy
Fp1-β SPD, µV²/Hz	-77±17	+19±31	,024	,746	,68	,496	,272
T3-β SPD, %	+9,0±5,6	-6,7±6,0	,031	,946	,11	,768	,356
C3-α SPD, %	+1,0±1,7	-7,7±3,3	,028	,845	,37	,606	,186

Using the information from tabl. 7 and repeating the procedure described above, we obtain an illustration of the neurophysiological support of individual changes in the functions of the hands (Fig. 2).

Table 7. Summary of Stepwise Analysis and Coefficients for Canonical Variables (changes in EEGs and HRVs parameters)

	Parameters of Wilk's Statistics					**Coefficients for Canonical Variables**		
Variables currently in the model	F to enter	p-level	Λ	F-va-Lue	p-level	Standar-dized	Struc-tural	Raw
Θ-rhythm Asymmetry, %	11,9	,005	,503	11,9	,005	-,157	,183	-,0101
Δ-rhythm Asymmetry, %	1,9	,207	,119	8,7	,006	2,242	,151	,1002
Β-rhythm Laterality, %	3,5	,095	,183	10,0	,002	-,873	,128	-,0300
F8-β SPD, µV²/Hz	4,3	,065	,254	9,8	,003	1,569	,074	,0199
HF HRV, %	1,1	,350	,050	8,5	,027	2,246	,061	,1696
Θ-rhythm Deviation, Hz	4,3	,064	,363	9,7	,004	1,011	-,095	1,150
LFnu HRV, %	1,7	,232	,151	9,0	,004	-2,272	-,088	-,1507
O1-β SPD, µV²/Hz	1,6	,300	,033	8,9	,049	-1,398	-,083	-,0080
O1-α SPD, µV²/Hz	1,2	,320	,064	9,2	,013	-2,632	-,075	-,0183
F4-θ SPD, %	3,0	,134	,079	10,0	,006	-2,139	-,061	-,2558
	r*=0,984; Wilks' Λ=0,033; $\chi^2_{(10)}$=24; p=0,007						**Constant**	-2,727

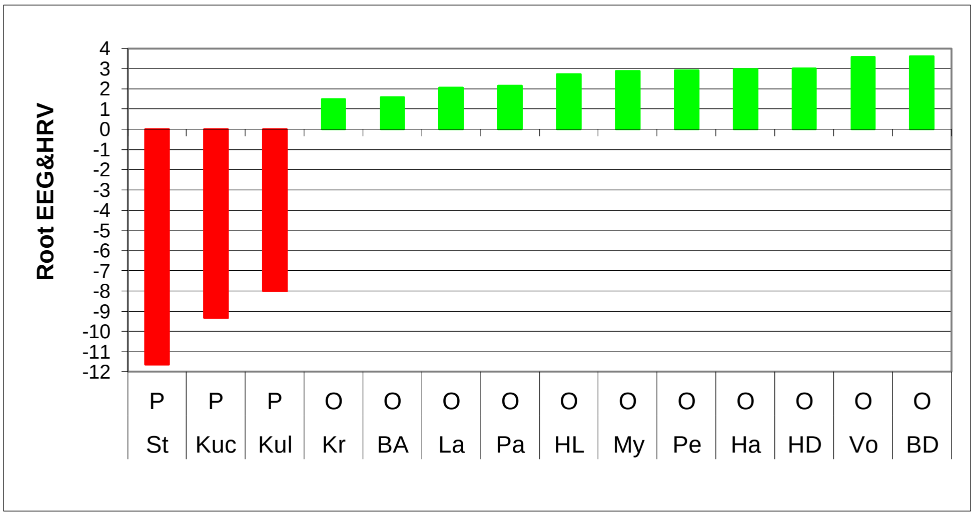

Fig. 2. Individual values of canonical Root of unfavorable (P) and favorable (O) changes in EEGs and HRVs parameters

Classification of clusters according to neurophysiological variables is also unmistakable (Table 8).

Table 8. Coefficients and Constants for Classification Functions of changes in EEGs and HRVs parameters

Variables currently in the model	Unfavorable changes (3) P=,214	Favorable changes (11) p=,786
Θ-rhythm Asymmetry, %	,0104	-,1138
Δ-rhythm Asymmetry, %	-,6247	,6057
Β-rhythm Laterality, %	,0625	-,3054
F8-β SPD, μV^2/Hz	-,1357	,1083
HF HRV, %	-,9475	1,1352
Θ-rhythm Deviation, Hz	-3,645	10,47
LFnu HRV, %	,9662	-,8841
O1-β SPD, μV^2/Hz	,0449	-,0530
O1-α SPD, μV^2/Hz	,0985	-,1265
F4-θ SPD, %	1,603	-1,538
Constants	-27,72	-16,82

After expanding the database for discriminant analysis at the expense of GDVs parameters, the model turned on only Entropy of the Gas Discharge Image in Left projection with filter, the value of which significantly decreased with adverse changes in the functions of the hands, remaining unchanged with favorable changes. Worthy of attention is also not included in the model changes, namely an increase in the Area of the GD Image in the frontal projection without filter, coupled with a decrease in its Entropy in the Frontal projections with filter in members of first cluster (Table 9 and 10).

Table 9. Discriminant Function Analysis Summary. Changes in EEGs, HRVs and GDVs parameters
Step 9, N of vars in model: 9; Grouping: 2 grps
Wilks' Lambda: 0,0166; approx. $F_{(9,4)}$=26; p=0,003

Variables currently in the model	Unfavorable changes (3)	Favorable changes (11)	Wilks' Λ	Parti-al Λ	F-re-move	p-level	Tole-rancy
Θ-rhythm Asymmetry, %	-27±12	+8±4	,017	,985	0,1	,814	,562
Δ-rhythm Asymmetry, %	-33±13	+9±7	,080	,207	15,3	,017	,169
B-rhythm Laterality, %	-54±3	-8±10	,026	,638	2,3	,207	,354
Entropy GDI Left (f)	-0,27±0,04	+0,03±0,04	,078	,212	14,9	,018	,164
F8-β SPD, μV^2/Hz	-32±22	+41±27	,023	,719	1,6	,279	,481
HF HRV, %	-3,4±2,8	+6,6±4,3	,023	,714	1,6	,275	,113
Θ-rhythm Deviation, Hz	+1,00±0,29	-0,05±0,30	,031	,539	3,4	,138	,391
LFnu HRV, %	+5,2±3,9	-11,2±4,9	,081	,206	15,4	,017	,028
F4-θ SPD, %	+4,3±1,7	-2,1±2,9	,023	,714	1,6	,275	,113
Variables currently not in the model			Wilks' Λ	Parti-al Λ	F to enter	p-level	Tole-rancy
Fp1-β SPD, μV^2/Hz	-77±17	+19±31	,016	,977	,07	,808	,300
Entropy GDI Frontal (f)	-0,18±0,13	+0,06±0,05	,016	,980	,06	,822	,131
T3-β SPD, %	+9,0±5,6	-6,7±6,0	,016	,990	,03	,872	,472
C3-α SPD, %	+1,0±1,7	-7,7±3,3	,016	,948	,17	,712	,387
O1-β SPD, μV^2/Hz	+178±81	-5±58	,013	,765	,92	,408	,221
O1-α SPD, μV^2/Hz	+116±20	-20±50	,014	,838	,58	,502	,054
Area GDI Frontal, kPx	+3,94±2,12	-0,94±0,99	,014	,858	,50	,532	,082

Table 10. Summary of Stepwise Analysis and Coefficients for Canonical Variables (changes in EEGs, HRVs and GDVs parameters)

	Parameters of Wilk's Statistics					**Coefficients for Canonical Variables**		
Variables currently in the model	F to enter	p-level	Λ	F-va-Lue	p-level	Standar dized	Struc-tural	Raw
θ-rhythm Asymmetry, %	11,9	,005	,503	11,9	,005	,167	-,129	,0108
δ-rhythm Asymmetry, %	2,6	,160	,081	9,8	,006	-2,182	-,106	-,0975
β-rhythm Laterality, %	3,5	,095	,183	10,0	,002	-1,020	-,091	-,0350
Entropy GDI Left (f)	2,2	,182	,115	9,0	,005	-2,211	-,089	-13,50
F8-β SPD, μV^2/Hz	4,3	,065	,254	9,8	,003	-,771	-,052	-,0098
HF HRV, %	1,6	,275	,017	26,3	,003	1,605	-,043	,1212
θ-rhythm Deviation, Hz	4,3	,064	,363	9,7	,004	1,094	,067	1,244
LFnu HRV, %	1,7	,232	,151	9,0	,004	5,369	,063	,3561
F4-θ SPD, %	3,0	,134	,079	10,0	,006	2,817	,043	,3368
	r*=0,992; Wilks' Λ=0,017; $\chi^2_{(9)}$=31; $p<10^{-3}$					**Constant**		,7416

Despite the seemingly slight structural changes in the discriminatory model the power of discrimination, estimated by the criterion Wilks' Lambda, increases from 0,0327 (approx. $F_{(10,3)}$=8,89; p=0,049) to 0,0166 (approx. $F_{(9,4)}$=26; p=0,003) as well as D^2_M between clusters increases from 176 (F=7,33; p=0,064) to 352 (F=22; p=0,005). The increase in the power of discrimination is noted in Fig. 3.

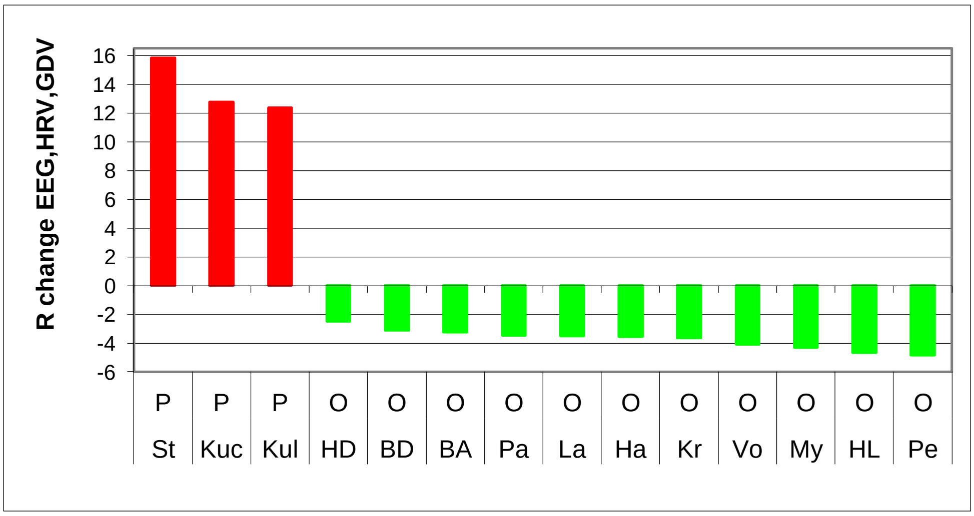

Fig. 3. Individual values of canonical Root of unfavorable (P) and favorable (O) changes in EEGs, HRVs and GDVs parameters

The classification is expected to remain unmistakable (Table 11).

Table 11. Coefficients and Constants for Classification Functions of changes in EEGs, HRVs and GDVs parameters

Variables currently in the model	Unfavorable changes (3)	Favorable changes (11)
	p=,214	p=,786
θ-rhythm Asymmetry, %	,138	-,049
δ-rhythm Asymmetry, %	-1,245	,450
β-rhythm Laterality, %	-,480	,128
Entropy GDI Left (f)	-174	60,5
F8-β SPD, $\mu V^2/Hz$	-,131	,039
HF HRV, %	1,569	-,537
θ-rhythm Deviation, Hz	16,754	-4,862
LFnu HRV, %	4,529	-1,656
F4-θ SPD, %	4,251	-1,600
Constants	-85,38	-10,75

CONCLUSION

Despite the small contingent of the observed children with spastic form of cerebral palsy, we have proved that the differently directed changes in the parameters of hand functions caused by two-week rehabilitation course by Kozyavkin© method are due to differently directed changes in parameters of EEG, HRV as well as GDV. GDV is a completely suitable non-invasive method for assessing the effectiveness of rehabilitation.

PERSPECTIVES FOR FURTHER STUDIES

The results presented in this and previous [17,18] articles give us reason to assume that increasing the effectiveness of rehabilitation, perhaps, is possible through additional electrostimulation of the vagus nerve and/or certain scalp loci.

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ACCORDANCE TO ETHICS STANDARDS

Tests in patients are conducted in accordance with positions of Helsinki Declaration 1975, revised and complemented in 2002, and directive of National Committee on ethics of scientific researches. During realization of tests from parents all participants the informed consent is got and used all measures for providing of anonymity of participants.

For all authors any conflict of interests is absent.

REFERENCES

1. Kozyavkin VI. The system of intensive neurophysiological rehabilitation [in Ukrainian]. Medical Hydrology and Rehabilitation. 2003; 1(2): 63-67.
2. Kozyavkin VI, Sak NM, Kachmar OO, Babadahly MO. Basics of Rehabilitation of Motor Disfunctions by Kozyavkin method [in Ukrainian]. L'viv: Ukrainian technologies; 2007: 192 p.
3. Kozyavkin VI, Babadahly MO, Lun HP, Kachmar OO, Hordiyevych SM, Lysovych VI, Voloshyn BD. Intensive Neurophysiological Rehabilitation System – the Kozyavkin method. A manual for Rehabilitation Specialists. L'viv: "Papuga" Publishing Hous; 2012: 240 p.
4. Kozyavkin VI, Kozyavkina OV, Kozyavkina NV, Gordiyevych MS, Lysovych VI, Voloshyn TV, Zukow W, Popovych IL. Estimation of effectivenes of spine biomechanical correction Kozyavkin method (INRS) in children with spastic form of cerebral palsy. Journal of Education, Health and Sport. 2015; 5(2): 208-217.
5. Kozyavkin VI, Kozyavkina NV, Kozyavkina OV, Gordiyevych MS, Lysovych VI, Voloshyn TB, Popovych IL**,** Zukow W. Effect of spine biomechanical correction Kozyavkin's method (INRS) on components of muscle tone in children with spastic form of Cerebral Palsy and its possible prediction. Journal of Education, Health and Sport. 2015; 5(1): 11-30.
6. Kachmar O, Voloshyn T, Hordiyevych M. Changes in Muscle Spasticity in Patients With Cerebral Palsy After Spinal Manipulation: Case Series. J Chiropr Med. 2016; 15: 299-304.
7. Padko VO. The state of the autonomic nervous system in patients with cerebral palsy [in Ukrainian]. In: Intensive Neurophysiological Rehabilitation System (the Kozyavkin VI method). Scientific developments. Under the general editorship of Koziavkin VI. L'viv-Truskavets': Institute of Medical Rehabilitation Problems; 2001: 56-61.
8. Kerppers II, Arisawa EAL, Oliveira LVF, Sampaio LMM, Oliveira CS. Heart rate variability in individuals with cerebral palsy. Arch Med Sci. 2009; 5(1): 45-50.
9. Amichai T, Katz-Leurer M. Heart rate variability in children with cerebral palsy: Review of the literature and mata-analysis. NeuroRehabilitation. 2014; 35: 113-122.
10. Popovych IL, Lukovych YuS, Korolyshyn TA, Barylyak LG, Kovalska LB, Zukow W. Relationship between the parameters heart rate variability and background EEG activity in healthy men. Journal of Health Sciences. 2013; 3(4): 217-240.
11. Popovych IL, Kozyavkina OV, Kozyavkina NV, Korolyshyn TA, Lukovych YuS, Barylyak LG. Correlation between Indices of the Heart Rate Variability and Parameters of Ongoing EEG in Patients Suffering from Chronic Renal Pathology. Neurophysiology. 2014; 46(2): 139-148.
12. Korotkov KG. Basics GDV Bioelectrography [in Russian]. SPb: SPbGITMO(TU); 2001: 360 p.
13. Korotkov KG, Matrauers P, Orlov DV, Williams BO. Application of electrophoton capture (EPC) analysis based on gas discharge visualization (GDV) technique in medicine. A systematic review. J Altern Complement Med. 2010; 16(1): 13-25.
14. Babelyuk VE, Gozhenko AI, Dubkova GI, Babelyuk NV, Zukow W, Kovbasnyuk MM, Popovych IL. Causal relationships between the parameters of gas discharge visualization and principal neuroendocrine factors of adaptation. Journal of Physical Education and Sport. 2017; 17(2): 624-637.
15. Babelyuk VY, Dubkowa GI, Korolyshyn TA, Holubinka SM, Dobrovol's'kyi YG, Zukow W, Popovych IL. Operator of Kyokushin Karate via Kates increases synaptic efficacy in the rat Hippocampus, decreases C3-θ-rhythm SPD and HRV Vagal markers, increases virtual Chakras Energy in the healthy humans as well as luminosity of distilled water in

vitro. Preliminary communication. Journal of Physical Education and Sport. 2017; 17(1): 383-393.
16. Gozhenko AI, Sydoruk NO, Babelyuk VYe, Dubkowa GI, Flyunt VR, Hubyts'kyi VYo, Zukow W, Barylyak LG, Popovych IL. Modulating effects of bioactive water Naftussya from layers Truskavets' and Pomyarky on some metabolic and biophysic parameters at humans with dysfunction of neuro-endocrine-immune complex. Journal of Education, Health and Sport. 2016; 6(12): 826-842.
17. Babelyuk VY, Dubkova HI, Korolyshyn TA, Mysula IR, Popovych DV, Popovych IL, Zukow W. Relationships between caused by Kozyavkin© method changes in parameters of manual function and electroencephalogram, heart rate variability as well as gas discharge visualization in children with spastic form of cerebral palsy. Journal of Education, Health and Sport. 2018; 8(4): 159-194.
18. Popovych IL, Babelyuk VY, Dubkova HI, Korolyshyn TA, Zukow W. Relationships between changes in parameters of manual function and electroencephalogram, heart rate variability as well as gas discharge visualization in children with spastic form of cerebral palsy caused by Kozyavkin© method. Experimental and Clinical Physiology and Biochemistry. 2018; 1(81): 39-50.
19. Russell DJ, Avery LM, Walter SD, Hanna SE, Bartlett DJ, Rosenbaum PL, Palisano RJ, Gorter JW. Development and validation of item sets to improve efficiency of administration of the 66-item Gross Motor Function Measure in children with cerebral palsy. Dev Med Child Neur. 2010; 52(2): 48-54.
20. Eliasson AC, Krumlinde SL, Rösblad B, Beckund E, Arner M, Öhrvall AM, Rosenbaum P. The Manual Ability Classification System (MACS) for children with cerebral palsy: scale development and evidence of validity and rehabilitee. Dev Med Child Neur. 2006; 48: 549-554.
21. Lafayette Instrument Hand Dynamometer. User instructions: 10 p.
22. Mathiowetz V, Federman S, Wiemer D. Box and Block Test of Manual Dexterity: Norms for 6-19 Year Olds. Canad J Occup Ther. 1985; 52(5): 241-245.
23. Poole JL, Burtner PA, Torres TA, McMullen CK, Markham A, Marcum ML, Anderson JB, Qualls C. Measuring Dexterity in Children using the Nine Hole Peg Test. J Hand Ther. 2005; 18(3): 348-351.
24. Wang YC, Magasi SR, Bohannon RW, Reuben DB, McCreath HE, Bubela DJ, Gershon RC, Rymer WZ. Assessing Dexterity Function: A Comparison of Two Alternatives for the NIH Toolbox. J Hand Ther. 2011; 24(4): 313-321.
25. Lindberg PG, Gäverth J, Islam M, Fagergren A, Borg J, Forssberg H. Validation of a new biomechanical model to measure muscle tone in spastic muscles. Neurorehabil Neural Repair. 2011; 25(7): 617-625.
26. Gäverth J, Sandgren M, Lindberg PG, Forssberg H, Eliasson ACh. Test-retest and inter-rater reliability of a method to measure wrist and finger spasticity. J Rehabil Med. 2013; 45(7): 630-636.
27. Gäverth J, Eliasson ACh, Kullander K, Jörgen B, Lindberg PG, Forssberg H. Sensitivity of the NeuroFlexor method to measure change in spasticity after treatment with botulinum toxin A in wrist and finger muscles. J Rehabil Med. 2014; 46(7): 629-634.
28. Kozyavkin VI, Kachmar OO, Voloshyn TB, Hordiyevych MS. Muscular tone components and methods of quantitative measurement of spasticity [in Ukrainian]. J of Neuroscience of BM Mankovskyi. 2015; 3(1): 72-76.
29. Heart Rate Variability. Standards of Measurement, Physiological Interpretation, and Clinical Use. Task Force of ESC and NASPE. Circulation. 1996; 93(5): 1043-1065.
30. Berntson GG, Bigger JT jr, Eckberg DL, Grossman P, Kaufman PG, Malik M, Nagaraja HN, Porges SW, Saul JP, Stone PH, Van der Molen MW. Heart Rate Variability: Origines, methods, and interpretive caveats. Psychophysiology. 1997; 34: 623-648.

31. Baevskiy RM, Ivanov GG. Heart Rate Variability: theoretical aspects and possibilities of clinical application [in Russian]. Ultrazvukovaya i funktsionalnaya diagnostika. 2001; 3: 106-127.
32. Aldenderfer MS, Blashfield RK. Cluster analysis (Second printing, 1985) [trans. from English in Russian]. In: Factor, Discriminant and Cluster Analysis. Moskva: Finansy i Statistika. 1989: 139-214.
33. Mandel ID. Cluster analysis [trans. from English in Russian]. Moskva: Finansy i Statistika. 1988. 176 p.
34. Klecka WR. Discriminant Analysis [trans. from English in Russian] (Seventh Printing, 1986). In: Factor, Discriminant and Cluster Analysis. Moskva: Finansy i Statistika. 1989: 78-138.
35.